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F-14 ROTARY BALANCE TESTS FOR AN ANGLE-OF-ATTACK RANGE OF 0° TO 90°

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A 1/12-scale model of the F-14 was tested on the rotary balance located in the Langley Spin Tunnel. Data were obtained for the basic airplane in the maneuver configuration with various control settings at three wing sweeps. The data were supplied to the Naval Air Development Center on magnetic tape. This report presents a description of these tests and the information supplied on the data tape, as well as a list of spin modes predicted for the F-14 utilizing the rotary balance data.

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INTRODUCTION

The Naval Air Development Center intends to conduct high angle of attack studies on their Dynamic Flight Simulator modelling the Navy/Grumman F-14 airplane. As a part of this effort, rotary balance wind tunnel force tests of an F-14 model were conducted to provide a rotational aerodynamic data base up to 90° angle of attack.

A 1/12-scale model of the F-14 was tested on the rotary balance located in the Langley Spin Tunnel. Data were obtained for the basic airplane in the maneuver configuration with various control settings at three wing sweeps. The data were supplied to the Naval Air Development Center on magnetic tape. This report presents a description of these tests and the information supplied on the data tape, as well as a list of spin modes predicted for the F-14 utilizing the rotary balance data.

SYMBOLS

The units for physical quantities used herein are presented in U.S. Customary Units.

b wing span, ft

c mean aerodynamic chord, ft

C_A axial-force coefficient, $\frac{\text{Axial force}}{qS}$, positive aft along the body X-axis

C_D drag coefficient, $\frac{\text{Drag force}}{qS}$

C_N normal-force coefficient, $\frac{\text{Normal force}}{qS}$, positive upward from the body X-Y plane

C_Y side-force coefficient, $\frac{\text{Side force}}{qS}$, positive out the right wing

C_L lift coefficient, $\frac{\text{Lift force}}{qS}$

C_l body-axis rolling-moment coefficient, $\frac{\text{Rolling moment}}{qSb}$

$C_{l_{stab.}}$ stability-axis rolling-moment coefficient, $\frac{\text{Stab.-axis roll moment}}{qSb}$

C_m pitching-moment coefficient, $\frac{\text{Pitching moment}}{qSc}$

C_n body-axis yawing-moment coefficient, $\frac{\text{Yawing-moment}}{qSb}$

$C_{n_{stab.}}$ stability-axis yawing-moment coefficient, $\frac{\text{Stab.-axis yaw moment}}{qSb}$

q free-stream dynamic pressure, lb/ft^2

S wing area, ft^2

α angle of attack, deg

β angle of sideslip, deg

Ω angular velocity about spin axis, rad/sec

$\Omega b/2V$ spin coefficient, positive for clockwise spin

δ_d differential horizontal tail deflection, positive when right surface is down, $(\delta_{h_{right}} - \delta_{h_{left}})/2$, deg

δ_h symmetrical horizontal tail deflection, positive when trailing edge is down, deg

δ_r rudder deflection, positive when trailing edge is to the left, deg

δ_{sp} spoiler deflection, positive for right wing spoiler deflected trailing edge up

Λ_{LE} sweep angle of the wing leading edge

Abbreviations

cg center of gravity

RPM revolutions per minute

TE trailing edge

TEST EQUIPMENT

A rotary balance measures the forces and moments acting on a model while it is subjected to rotational flow conditions. A photograph and sketch of the rotary balance apparatus installed in the Langley Spin Tunnel are shown in figures 1 and 2, respectively. The system's rotary arm, which rotates about a vertical axis at the tunnel center, is supported by a horizontal boom and is driven by a motor mounted external to the test section.

A NASA six-component strain gauge balance, affixed to the bottom of the rotary balance apparatus and mounted inside the model, is used to measure the normal, lateral, and longitudinal forces, and the yawing, rolling, and pitching moments acting about the model body axis. Controls located outside of the tunnel test section are used to activate motors on the rotary rig, which position the model to the desired attitude. The angle-of-attack range of the rig is 0° to 90°, and the sideslip angle range is $\pm 15^{\circ}$. Spin radius and lateral displacement motors are used to position the moment center of the balance on, or at a specific distance from, the spin axis. (This is done for each combination of angle of attack and sideslip angle.) It is customary to mount the balance to the model such that its moment center is at the location about which the aerodynamic moments are desired. Electrical currents from the balance and to the motors on the rig are conducted through slip rings. Figure 2 illustrates various components of the rig and shows how the rig is positioned in angle of attack and sideslip.

The system is capable of rotating up to 90 rpm in either direction. A range of $\Omega b/2V$ values can be obtained by adjusting rotational speed and/or tunnel air flow velocity. (Static aerodynamic forces and moments are obtained when Ω=0.)

The data acquisition, reduction, and presentation system is composed of a 12-channel scanner/voltmeter, a mini-computer with internal printer, a plotter, and a CRT display. This equipment permits data to be presented via on-line digital print-outs and/or graphical plots.

TEST PROCEDURES

Rotary aerodynamic data are obtained in two steps. First, the inertial forces and moments (tares) acting on the model at different attitudes and rotational speeds must be determined. Ideally, these inertial terms would be obtained by rotating the model in a vacuum, thus eliminating all aerodynamic forces and moments. As a practical approach, this is approximated closely by enclosing the model in a sealed spherical structure, which rotates with the model without touching it, such that the air immediately surrounding the model is rotated with it. As the rig is rotated at the desired attitude and rate, the inertial forces and moments generated by the model are measured and stored on magnetic tape for later use.

The second step is to remove the enclosure and record force and moment data with the air on. The tares, measured in step one, are then subtracted from these data, leaving only the aerodynamic forces and moments, which are converted to coefficient form and stored on magnetic tape.

MODEL

A 1/12-scale model of the Navy/Grumman F-14 fighter airplane was constructed of balsa and plywood. A three-view drawing of the model is shown in figure 3, dimensional characteristics of the basic model are listed in Table I , and a photograph of the model installed on the rotary balance located in the Langley Spin Tunnel is presented in figure 1.

The model control surfaces could be set at any position prior to testing. The maximum deflections for the control surfaces were:

rudder (deg)	30 right, 30 left
symmetrical horizontal tail (TE)	35 up, 10 down
differential horizontal tail (TE)	12 up, 12 down
spoilers (deg)	55

Additionally, the glove vane could be extended to 15° or retracted into the wing-glove and the maneuver flaps and slats could be extended for the maneuver configuration to 10° and 7° deflections, respectively.

Canards were also constructed which could be mounted on the forward fuselage sides, as shown in figure 4.

TEST CONDITIONS

The tests were conducted in the spin tunnel at a free-stream velocity of 25 ft/sec, which corresponds to a Reynolds number of approximately 130,000 based on wing chord. All the configurations were tested through an angle-of-attack range of 0° to 90° in 5° increments, unless otherwise noted in Table II. For all the tests, the spin axis passed through the full-scale airplane nominal cg location (0.16c). For each angle of attack, data were obtained at rotation rates yielding the following $\Omega b/2V$ values, rounded to two decimal places: 0., 0.07, 0.14, 0.27, 0.41, 0.54, in both clockwise (positive) and counter-clockwise directions.

DATA PRESENTATION

Table II identifies the configurations tested and their corresponding file names. The files are written in the order shown, on a nine-track data tape. The data tape was produced by a CDC Computer and should be read as a stranger tape with standard blocking at 1600 bpi. All other parameters are the defaults. The data within each file is arranged in the following order: The first 68 characters in each file provide identification information consisting of the date the tests were performed, the name of the model (F-14), the configuration tested, and a run number used at the spin tunnel for bookkeeping purposes. These data are written in A8,2A25,E10.3 format.

The remainder of each file contains the data measured during the rotary balance testing of the given configuration, beginning with the smallest angle of attack and most negative spin rate ($\Omega b/2V$). The data are ordered such that first the angle of attack is held constant while the $\Omega b/2V$ increases to its maximum, followed by the data for the next larger angle of attack, beginning again at the most negative $\Omega b/2V$. There will be two sets of zero $\Omega b/2V$ data at each α, because static ($\Omega b/2V=0$) values were measured twice.

Each data point consists of 171 characters, which present the following data in order:

angle of attack, sideslip angle, point number, C_A, C_Y, C_N, C_l, C_m, C_n, $\Omega b/2V$, C_L, C_D, $C_{l_{stab.}}$,

$C_{n_{stab.}}$, raw voltages for axial force, side force,

normal force, roll moment, pitch moment, and yaw moment, and, lastly, rotary rig RPM.

These data are written using the following format:

2E9.2,E13.6,11F7.4,6F9.6,E9.2

All the moment data are presented for a cg position of 0.16c.

Unless otherwise designated in Table II, the airplane was tested in the maneuver configuration, which consisted of the glove vane and maneuver flaps and slats extended for the 22° and 50° wing sweeps. At 68° wing sweep, the glove vane was extended.

Predicted Spin Modes

A comparison of spin modes predicted using rotary balance data and experimental, free-spinning model results are presented in Table IV. The predicted spin mode characteristics agree well with the experimental results at 22° wing sweep. Both the predicted and experimental results indicate that sweeping the wings to 68° produces a slower, steeper spin mode, although the rotary balance data shows a greater influence of wing sweep than was observed in the spin tunnel results. The effect of wing sweep is primarily caused by improved damping of the yawing moment at high angles of attack as the wings are swept aft. This should also provide improved recovery characteristics with the wings swept aft, as was observed in the spin tunnel.

Spin modes with the stick aft ($-23^\circ \delta_h$) are significantly slower with pro-spin controls, and the results suggest that recoveries can, likewise, be improved by maintaining aft stick. This is due to improved yaw damping with the stick aft at high angles of attack.

When the airplane was configured with the canards shown in figure 4, steeper, slower spins resulted, as shown in Table V. This, again, results from greater yaw damping at the high angles of attack, which, in this case, is produced by the canards. The canards also eliminated a non-zero yawing moment at zero sideslip angle and rotation rate in the

40° to 70° angle-of-attack range. Therefore, the canards would be expected to eliminate the 64° right spin predicted with aft stick and neutral lateral controls, since this mode is a result of the yawing moment offset.

TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE 1/12-SCALE F-14 MODEL

Overall length, ft	5.16
Wing:	
Span (unswept), ft	5.34
Reference area, ft^2	3.92
Aspect ratio	7.28
Taper ratio	0.265
Sweep range, deg	22 to 68
Dihedral	$-1^{\circ}50'$
Root chord, in	13.93
Tip chord, in	3.69
Mean geometric chord, in	9.80
Incidence, deg:	
BL 8.025	+0.74
BL 32.07	-4.10
Pivot location	FS 43.68 BL 8.92
Horizontal tail:	
Span (overall), ft	2.73
Area (exposed), ft^2	0.97
Aspect ratio (exposed), each	2.56
Taper ratio	0.213
Leading edge sweep, deg	51
Dihedral, deg	-3.5
Root chord, in	12.38
Tip chord, in	2.64
Mean geometric chord, in	8.54
Airfoil section:	
Root	65A004.64
Tip	65A003.16
Vertical tail (twin fin):	
Span, ft	0.71
Area, ft^2	0.82
Aspect ratio, per fin	2.45
Taper ratio	0.358
Leading edge sweep,	$46^{\circ}54'$
Root chord, in	10.25
Tip chord, in	3.67
Mean geometric chord, in	7.48
Airfoil section	65A004.5
Toe-in angle, deg	0.85
Cant angle, deg outboard	5.0
Ventrals (twin ventrals, uncanted):	
Area, total, ft^2	0.13
LE sweep, deg	40

TABLE II.- CONFIGURATIONS TESTED AND DATA FILE INDEX

CONFIGURATION[e]	CONTROLS					FILE NAME
	δ_h deg	δ_{sp} deg	δ_d deg	δ_r deg	β deg	
HBW22HV	0	0	0	0	0	F14A
HBW22HVp+5[a]					+5	F14A3
HBW22HVp+10					+10	F14A4
HBW22HVp+15					+15	F14A1
HBW22HVp-15					-15	F14A2
HBW22HV-30r				-30	0	F14B4
HBW22HVp+15-30r					+15	F14B5
HBW22HV+7d-30r			+7		0	F14B14
HBW22HVp+15+7d-30r					+15	F14B15
HBW22HV+55sp+7d-30r		+55			0	F14B
HBW22HVp+15+55sp+7d-30r					+15	F14B1
HBW22HV+55sp+12d-30r			+12		0	F14B16
HBW22HVp+15+55sp+12d-30r					+15	F14B17
HBW22HV+55sp+7d			7	0	0	F14B2
HBW22HVp+15+55sp+7d					+15	F14B3
HBW22HV-23h	-23	0	0		0	F14B6
HBW22HVp+15-23h					+15	F14B7
HBW22HV-23h-30r				-30	0	F14B8
HBW22HVp+15-23h-30r					+15	F14B9
HBW22HV-23h+55sp+7d-30r		+55	+7		0	F14B22
HBW22HVp+15-23h+55sp+d-r					+15	F14B23
HBW22HV-23h+55sp+7d				0	0	F14B12
HBW22HVp+15-23h+55sp+7d					+15	F14B13
HBW22HV-35h[b]	-35	0	0		0	F14B28
HBW22HVp+15-35h[b]					+15	F14B29
HBW22HV+8h	+8	0	0	0	0	F14B24
HBW22HVp+15+8h					+15	F14B25
HBW22HV+8h+55sp+7d		+55	+7		0	F14B26
HBW22HVp+15+8h+55sp+7d					+15	F14B27
HBW22HVCLEAN[c]	0	0	0		0	F14CL
HBW22HV-pod[d]					0	F14MP
HBW22HVp+15-pod[d]					+15	F14MP1
HBcW22HV					0	F14C
HBcW22HVp+5[a]					+5	F14C3
HBcW22HVp+10[a]					+10	F14C2
HBcW22HVp+15					+15	F14C1
HBcW22HVp-15[a]					-15	F14C4

[a]static ($\Omega b/2V=0$) only

[b]tested for α=20-90° only

[c]glove vane in, slats and flaps retracted

[d]chin pod removed

[e]data were measured at a cg location of 0.16c for all configurations

TABLE II.- CONCLUDED

CONFIGURATION [e]	δ_h deg	δ_{sp} deg	δ_d deg	δ_r deg	β deg	FILE NAME
HBcW22HV+55sp+7d-30r	0	+55	+7	-30	0	F14C5
HBcW22HVp+15+55sp+7d-30r	↓				+15	F14C6
HBcW22HV-23h+sp+7d-r	-23				0	F14C7
HBcW22HVp+15-23h+sp+7d-r	↓	↓	↓	↓	+15	F14C8
HBW50HV	0	0	0	0	0	F14D2
HBW50HVp+15				↓	+15	F14D3
HBW50HV-30r				-30	0	F14D6
HBW50HVp+15-30r		↓	↓		+15	F14D7
HBW50HV+55sp+7d-30r		+55	+7		0	F14D
HBW50HVp+15+55sp 7d-30r				↓	+15	F14D1
HBW50HV+55sp+7d				0	0	F14D8
HBW50HVp+15+55sp+7d	↓	↓	↓	↓	+15	F14D9
HBW50HV-23h	-23	0	0	0	0	F14D4
HBW50HVp+15-23h				↓	+15	F14D5
HBW50HV-23h-30r				-30	0	F14D10
HBW50HVp+15-23h-30r		↓	↓		+15	F14D11
HBW50HV-23h+55sp+7d-r		+55	+7		0	F14D14
HBW50HVp+15-23h+sp+7d-r				↓	+15	F14D15
HBW50HV-23h+55sp+7d				0	0	F14D12
HBW50HVp+15-23h+55sp+7d	↓	↓	↓		+15	F14D13
HBW50HVCLEAN [c]	0	0	0		0	F14D16
HBW68HV					0	F14E2
HBW68HVp+15			↓	↓	+15	F14E3
HBW68HV+7d-30r			+7	-30	0	F14E
HBW68HVp+15+7d-30r			↓	↓	+15	F14E1
HBW68HVCLEAN [f]	↓	↓	0	0	0	F14E4

[c] glove vane in, slats and flaps retracted

[f] glove vane retracted

[e] data were measured at a cg location of 0.16c for all configurations

TABLE III.- CONFIGURATION DEFINITION

$$\underbrace{\text{H}}_{(1)}\underbrace{\text{BcW22HV}}_{(2)}\underbrace{\text{p+15}}_{(3)}\underbrace{\text{-23h+55sp+7d-30r}}_{(4)}$$

(1) The leading H designates the NASA strain gauge balance used for the tests; in this case the HCF03 balance.

(2) These characters define the configuration:

B = body, including wing-glove, nacelles, ventrals, and chin pod, unless otherwise specified

c = canards; if the c is omitted, the canards are not present

W22= wing and Λ_{LE}, in degrees

H = horizontal tail

V = vertical tails

(3) The sideslip angle is specified as p plus the angle in degrees. If no specification is present, this indicates zero sideslip angle.

(4) The control deflections are specified as the deflection in degrees (sign convention as specified in the Symbols list), followed by letters designating which surface, as follows:

h = symmetrical horizontal tail deflection, δ_h

sp = spoiler deflection, δ_{sp}

d = differential tail deflection, δ_d

r = rudder deflection, δ_r

If a surface is not designated, the deflection was zero. The maximum string length for the configuration description is 25 characters. To meet this requirement for some configurations, the degrees of deflection for some control surfaces were omitted; however, the sign of the deflection was retained. The deflections in such cases can be determined from Table II.

TABLE IV.- COMPARISON OF PREDICTED AND EXPERIMENTAL SPIN MODES

	CONTROLS				PREDICTED SPIN MODE				SPIN TUNNEL RESULTS			
Λ_{LE} deg	δ_h deg	δ_{sp} deg	δ_d deg	δ_r deg	α deg	$\frac{sec}{turn}$	$\frac{\Omega b}{2V}$	V ft/sec	α deg	$\frac{sec}{turn}$	$\frac{\Omega b}{2V}$	V ft/sec
22	-23[a]	0	0	0	64[b]	5.7	0.10	343	67[c]	6.2	0.10	334
	0				76	3.6	0.18	309	83	2.6	0.30	257
		+55[d]	+7	-30	85	1.9	0.35	299	86	2.1	0.34	279
			+12		86	1.7	0.44	266	88	1.7	0.47	253
		-55[d]	-7	+30	NO SPIN				NO SPIN			
50		+55[d]	+7	-30	79	2.6	0.28	280	86	1.9	0.37	284
68		0			70	3.8	0.18	295	79	2.9	0.21	320

[a]spin model results were with -30^{o} δ_h

[b]right spin only

[c]also no spin

[d]spin model did not have deflecting spoilers

TABLE V.- INFLUENCE OF CANARDS ON PREDICTED SPIN MODES

CONTROLS				BASIC AIRPLANE[a]				CANARDS EXTENDED[a]			
δ_h deg	δ_{sp} deg	δ_d deg	δ_r deg	α deg	$\frac{sec}{turn}$	$\frac{\Omega b}{2V}$	V ft/sec	α deg	$\frac{sec}{turn}$	$\frac{\Omega b}{2V}$	V ft/sec
0	0	0	0	76	3.6	0.18	309	69	4.7	0.14	323
↓	+55	+7	-30	85	1.9	0.35	299	77	3.4	0.21	283
-23	↓	↓	↓	75[b]	3.9	0.17	296				
				69[b]	4.9	0.13	308	63	6.9	0.09	328

[a] maneuver configuration, $\Lambda_{LE}=22^{\circ}$

[b] multiple spin modes

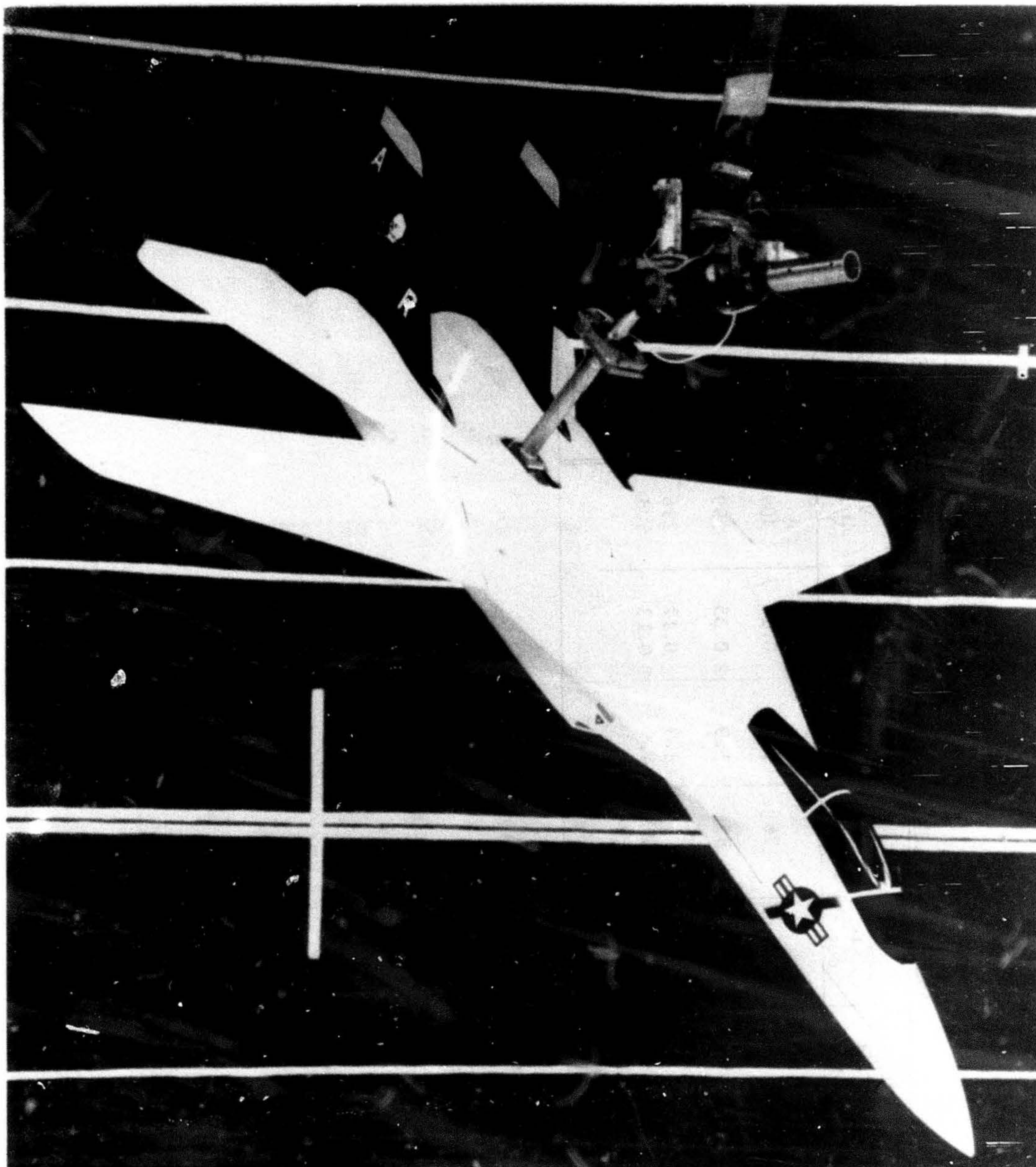
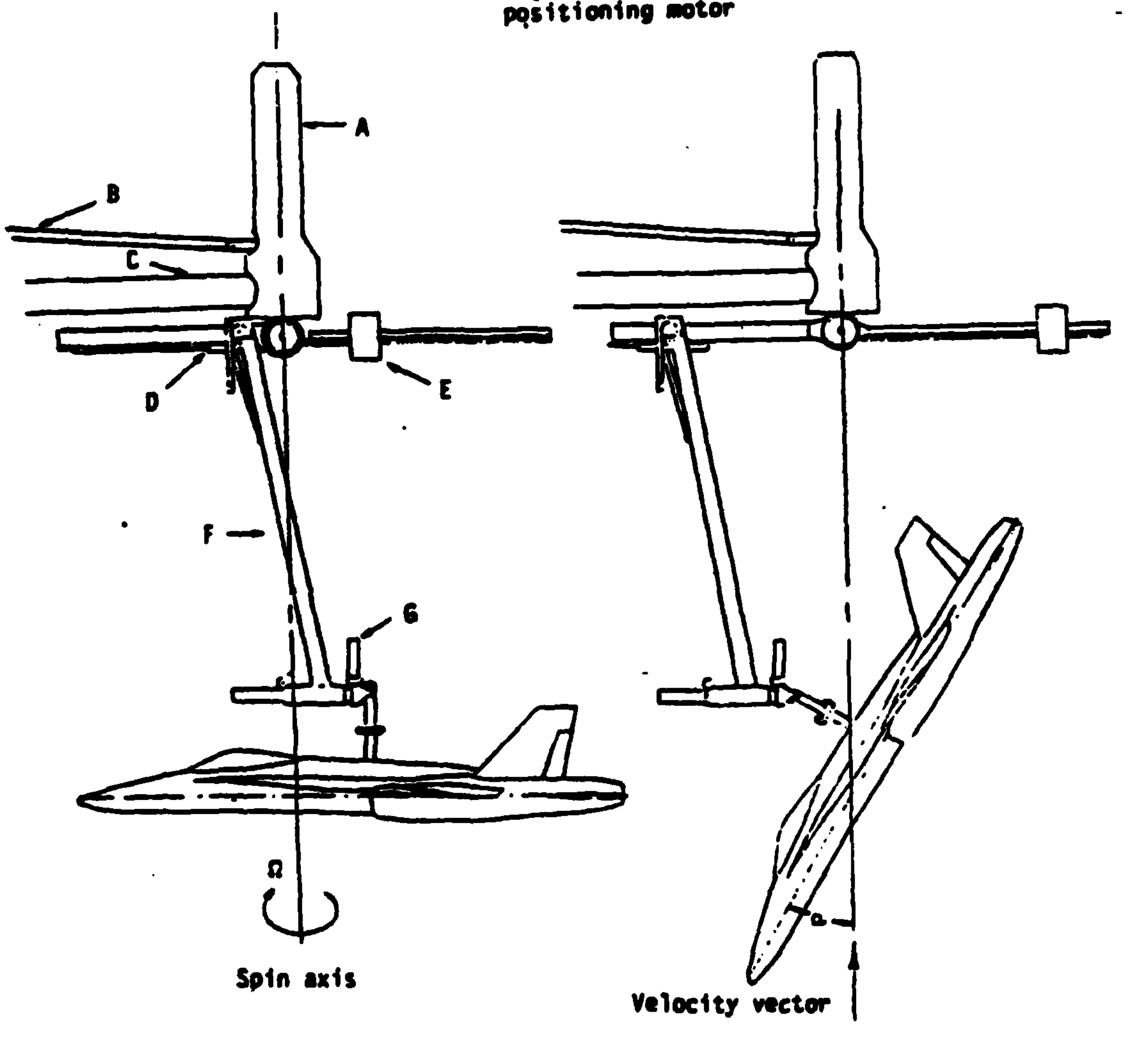


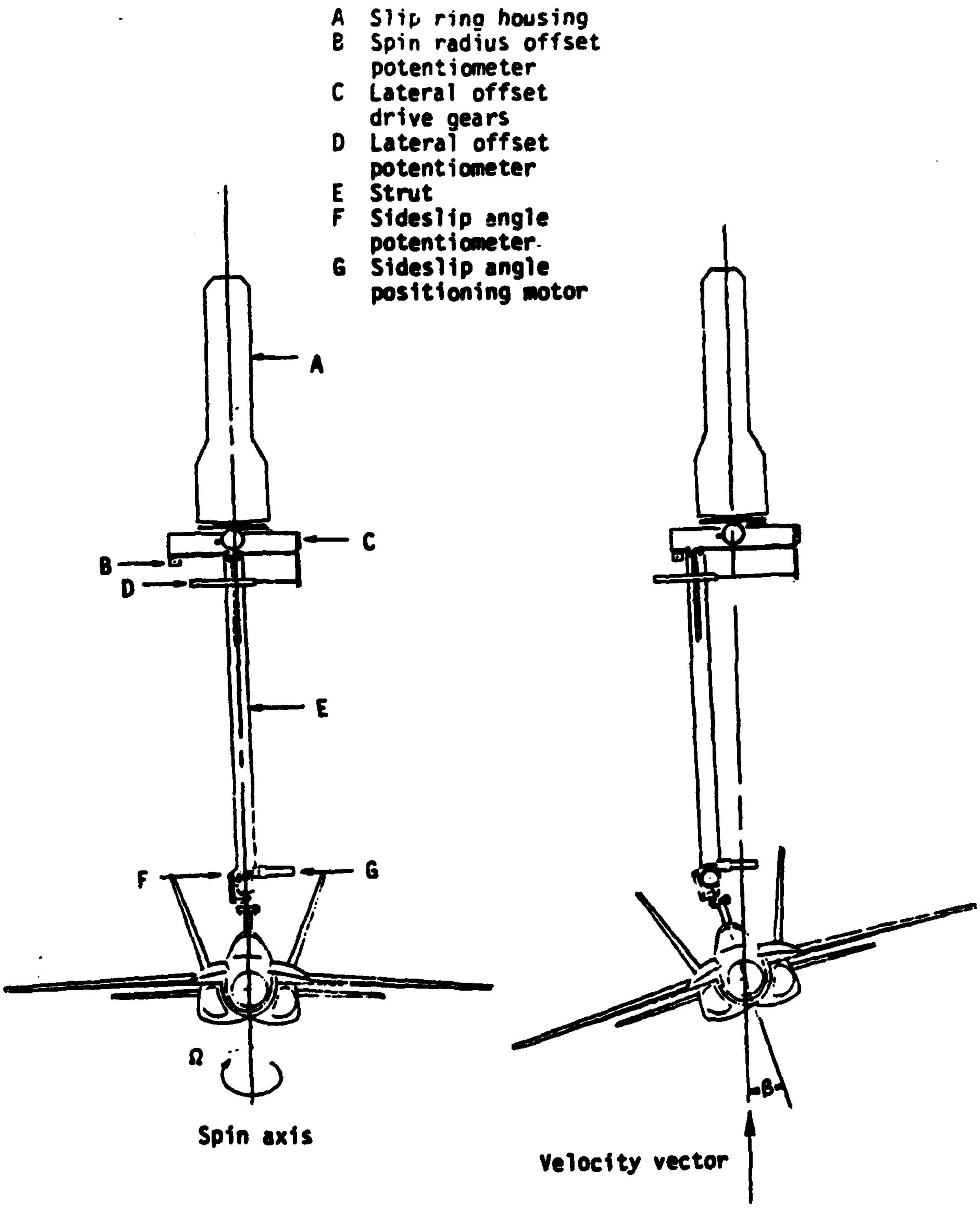
Figure 1.- Photograph of 1/12-scale model installed on the rotary balance apparatus.

A Slip ring housing
B Drive shaft
C Support boom
D Spin radius offset potentiometer
E Counterweight
F Strut
G Angle of attack positioning motor



(a) Side view of model.

Figure 2.- Sketch of rotary balance apparatus.



(b) Front view of model.

Figure 2.- Concluded.

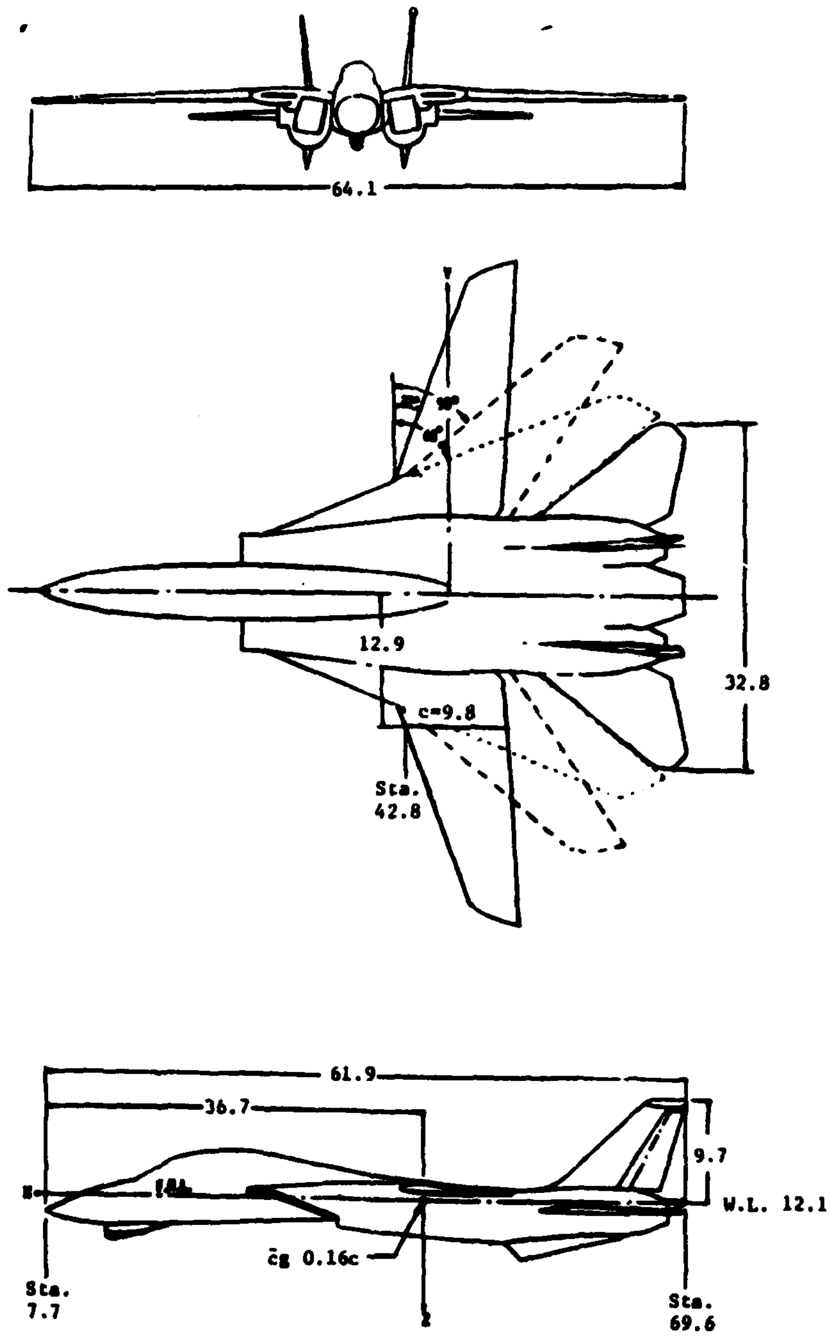


Figure 3.- Three-view sketch of 1/12-scale model. Dimensions are given in inches.

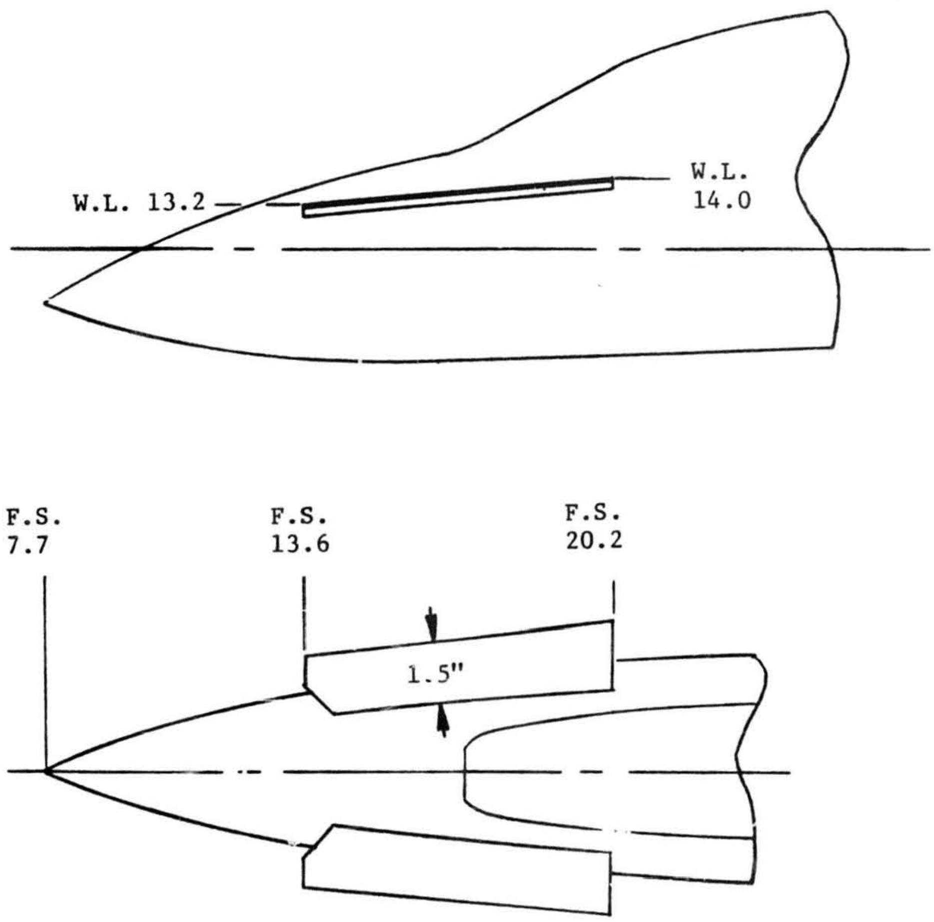


Figure 4.- Sketch of canards tested on the 1/12-scale F-14 model.

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